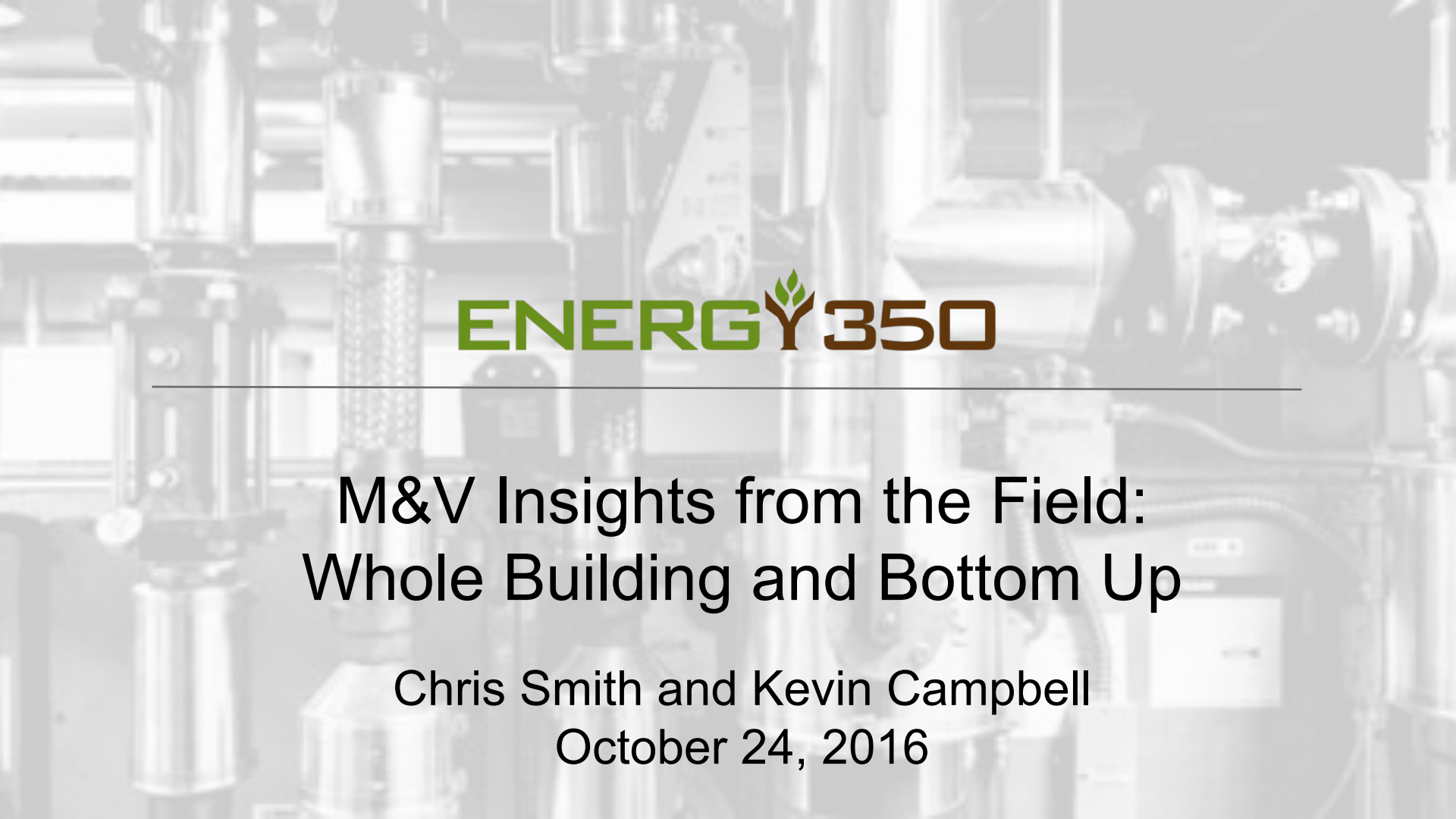
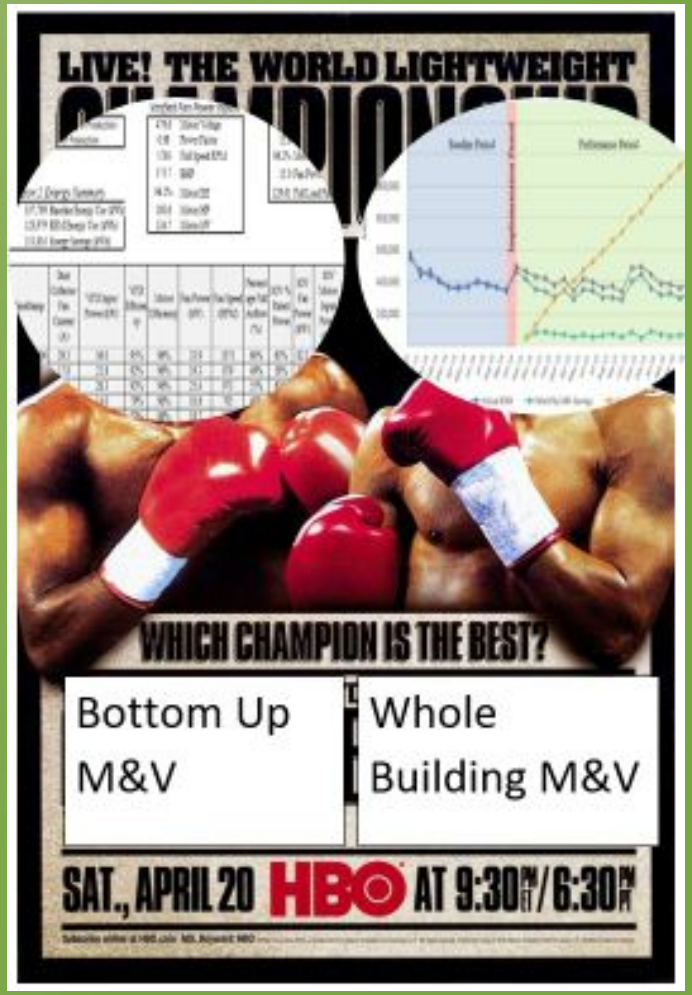
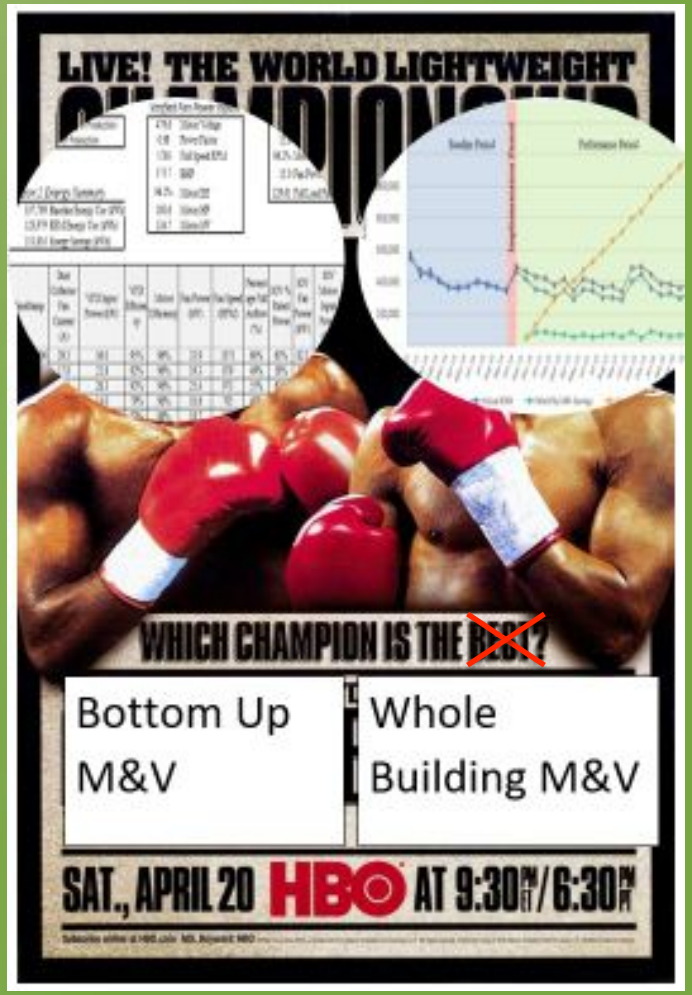


M&V Insights from the Field: Whole Building and Bottom Up

Chris Smith and Kevin Campbell

October 24, 2016


LIVE! THE WORLD LIGHTWEIGHT
WHICH CHAMPION IS THE BEST?
Bottom Up M&V
Whole Building M&V
SAT., APRIL 20 HBO AT 9:30PM ET/6:30PM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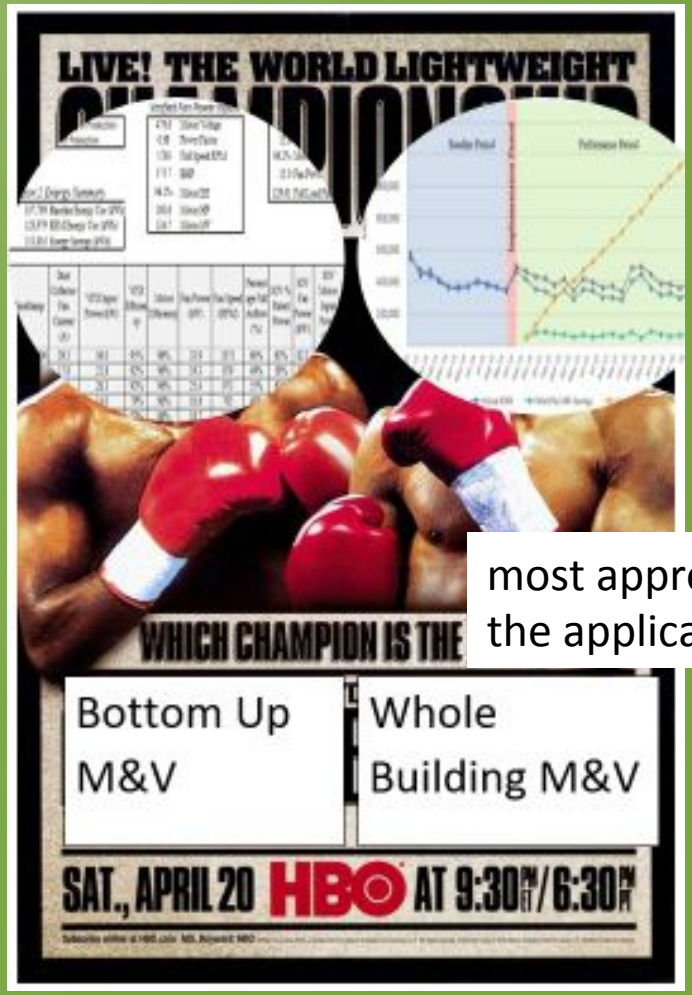


most appropriate for the application!

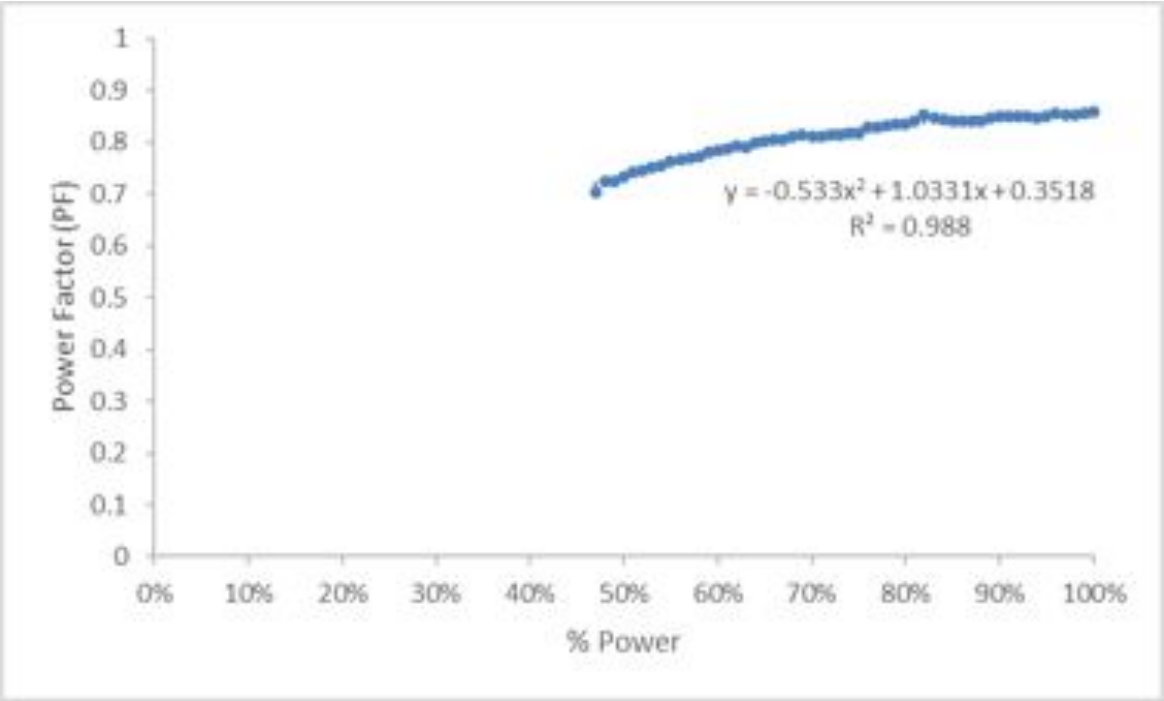
The Problem

- What would have happened absent the intervention?
- A simple case: LED street lighting retrofit

Simple Upgrade – Frozen ERV on Single Zone HVAC System

Simple Upgrade – Frozen ERV on Single Zone HVAC System

- Bottom up M&V – Equipment and methods matter



Complex Upgrade – RCx of Large Commercial Building

ENERGY 350

- Frozen ERV

Complex Upgrade – RCx of Large Commercial Building

- Disconnected Pressure Sensor

Complex Upgrade – RCx of Large Commercial Building

- Disabled/Broken Economizers

Complex Upgrade – RCx of Large Commercial Building

- Behavior Based Changes

Complex Upgrade – RCx of Large Commercial Building

- Thermostat in the Sun

Complex Upgrade – RCx of Large Commercial Building

ENERGY 350

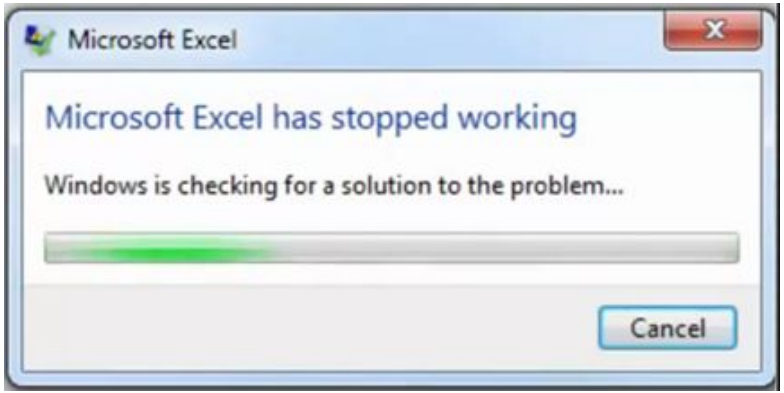
- Steam Venting Into Tower

Whole Building M&V – The Finer Points

- Requires unique skillset
  - Energy engineering and statistics
  - Resources and best practices are more accessible
- Models should not be developed in a vacuum
  - Knowledge of energy systems at the site
  - Understanding of other operational changes at the site
  - Knowledge of other energy projects at the site

Whole Building M&V – The Finer Points

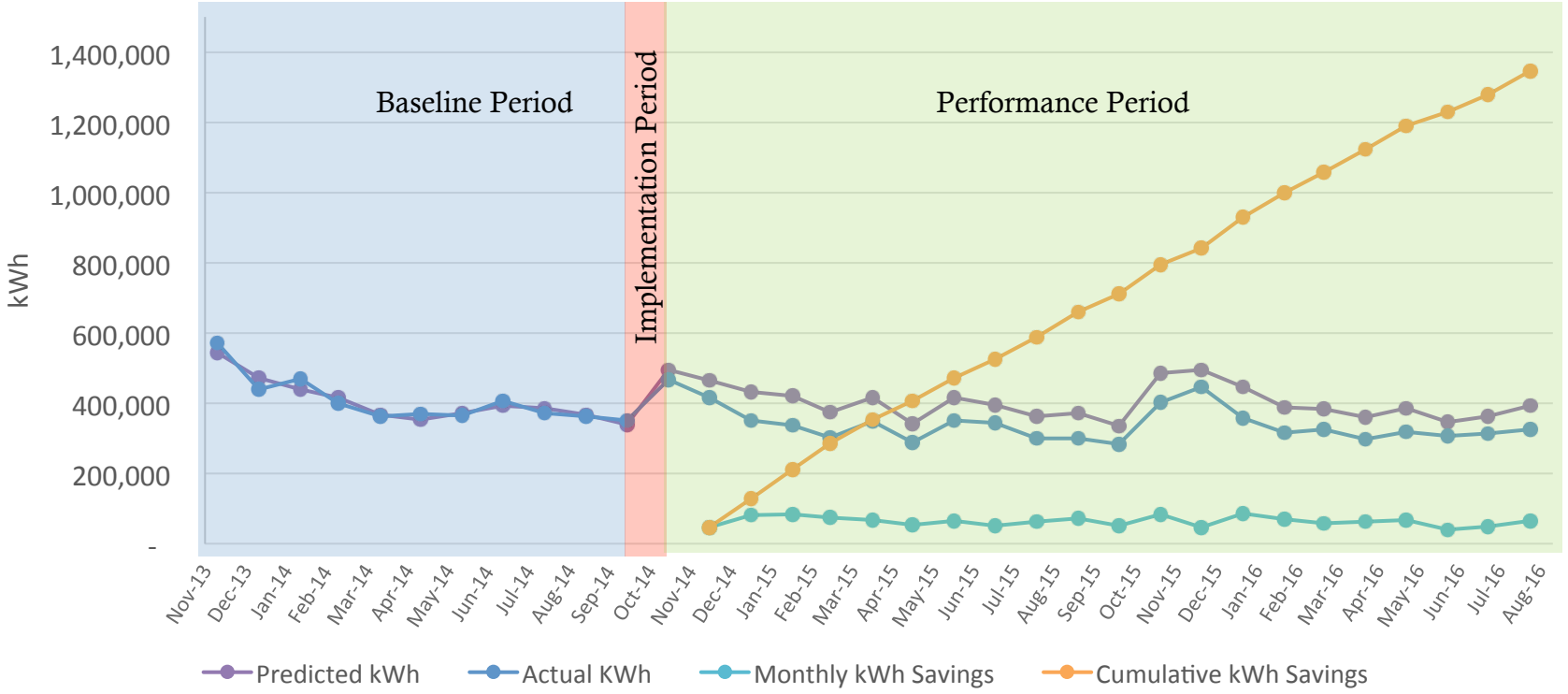
- Multitude of independent variable combinations
  - Industrial facilities
  - Commercial buildings
- The tool should match the application



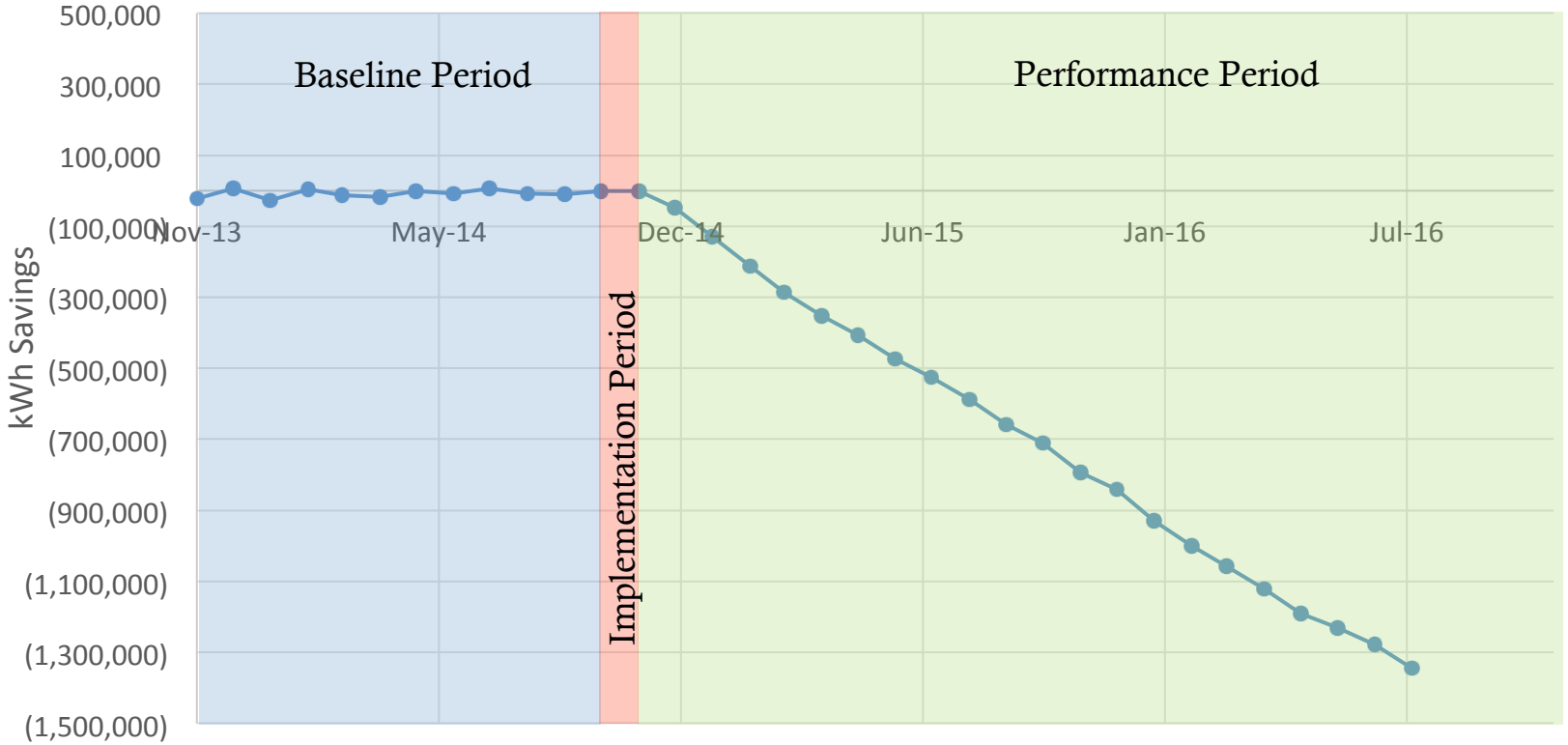
1000 Broadway Overview

- Energy Star Building
- Has implemented a number of capital projects, even LED lighting
- All electric, water cooled DX, VAV airside systems
- Through building tuning, saved 16% of energy use (794,386 kWh)
- Energy Star score went from 80 to 91
- Project included minimal capital equipment
- Savings have been measured and verified at the meter
- Building manager billed the expense to the triple net – means the tenants paid for it!

1000 Broadway Energy Performance



1000 Broadway Cumulative Sum of Savings (CUSUM)



1000 Broadway Energy Model – It's not that complicated!

ENERGY 350

- Regression model that uses independent variables to quantify savings statistically
- Interval data was not available, so model intervals are monthly
- Independent Variables
  - Cooling Degree Days
  - Heating Degree Days
  - Days in billing cycle
  - Occupancy was tracked, but was highly stable (full), so not used
- kWh Savings = Predicted kWh – Actual kWh

Modeling Stats - Transparency is Key!

ENERGY 350

Regression Statistics	
Multiple R	0.9502337
R Square	0.9029441
Adjusted R Square	0.8665481
Standard Error	23557.039
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	41301917881	1.38E+10	24.8089	0.000209711
Residual	8	4439472519	5.55E+08		
Total	11	45741390400			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	90262.869	163159.4102	0.553219	0.595231	-285983.406	466509.1433	-285983.4058	466509.1433
X Variable 1	6143.1231	5609.072805	1.095212	0.305298	-6791.422	19077.66817	-6791.421996	19077.66817
X Variable 2	276.25052	41.38871851	6.674537	0.000157	180.8079617	371.6930738	180.8079617	371.6930738
X Variable 3	505.5455	150.87427	3.350773	0.010069	157.6288071	853.4621879	157.6288071	853.4621879

1000 Broadway – Try calculating this at a Measure Level!

ENERGY 350

- Reduce scheduled occupied times (including exhaust fans)
  - Exhaust Fans run 4:00AM-7:00PM Mon-Fri, 8:00AM-Noon Sat – Should adjust schedule to match AHUs.
  - AHUs run 6:00AM-7:00PM Mon-Fri, 8:00AM-Noon Sat – Can we make this 7AM – 6PM? They actually go into occupied mode at 6:00, but with smart stop, they're coming on at 4:00 at least in this colder weather.
  - Can we shorten the lighting schedule?
- Enable morning warmup
- Command OA dampers fully closed during morning warmup if OAT<50
- SAT reset
- SP reset
- Fix broken economizers – Suspect economizers include:
  - AC9 – Seems to have very high minimum OA
  - AC10 – Compressor runs in cold weather
  - AC18 – Compressor runs in cold weather
  - AC21 – Compressor runs in cold weather
  - AC23 – Compressor runs in cold weather
- Fix broken VAV dampers
  - VAV 0925 Zone 25
  - VAV 1024 Zone 46
  - VAV 1316 Zone 15
  - VAV 1302 Zone 12
  - VAV 1326 Zone 10
  - VAV 1514 Zone 14
  - VAV 1928 Zone 17
  - VAV 2020 Zone 49
- Is fl 19 zone 23 temperature sensor working right? We're cooling it heavily and it says it's 77.
- Reduce Lobby & Theater OA
- Optimize CW Loop
  - Isolate the cooling tower bypass on the primary condenser water loop.
  - Reduce primary flow through HX – Do this until we get a similar DT on each side of the heat exchanger. We could also just measure flow on each side and balance primary flow to match secondary. We should leave the primary a little more than the secondary for when the lobby & theater units need cooling.
  - Program CW pumps to sequence up and down. I think there's plenty of time when we only need one of these.
  - Reduce primary CW DP setpoint from 17 PSI to ???
  - Program the secondary pumps to lead with the good one and bring the other one on once a week for an hour to exercise it. Also make sure it's programmed so that if the lead fails, the other comes on as a backup.
- Look to Reduce Lighting Schedule – RR and hall lights run 6AM-midnight and from midnight-2AM
- AC 18 economizer linkage needs to be connected to the actuator.
- What controls BR exhaust fans? They were running at 1:00 PM on Saturday.
- What's EF-1? It runs every day from 7AM-7PM.

We should do a lighting sweep at 8:00 PM. Then bring the hallway lights back on.

They don't clean Fri & we can shut lighting off at

- I reprogrammed the min cfm to 60.
- Why does the air valve not close more?
- Why does the air valve state cooling mode, yet fan & heat are on?

Economizers

-AC 9
-AC 10
-AC 11

SP 57 — Actual 67

up to AC 18

AC 12 → 10%

AC 17 → 10%

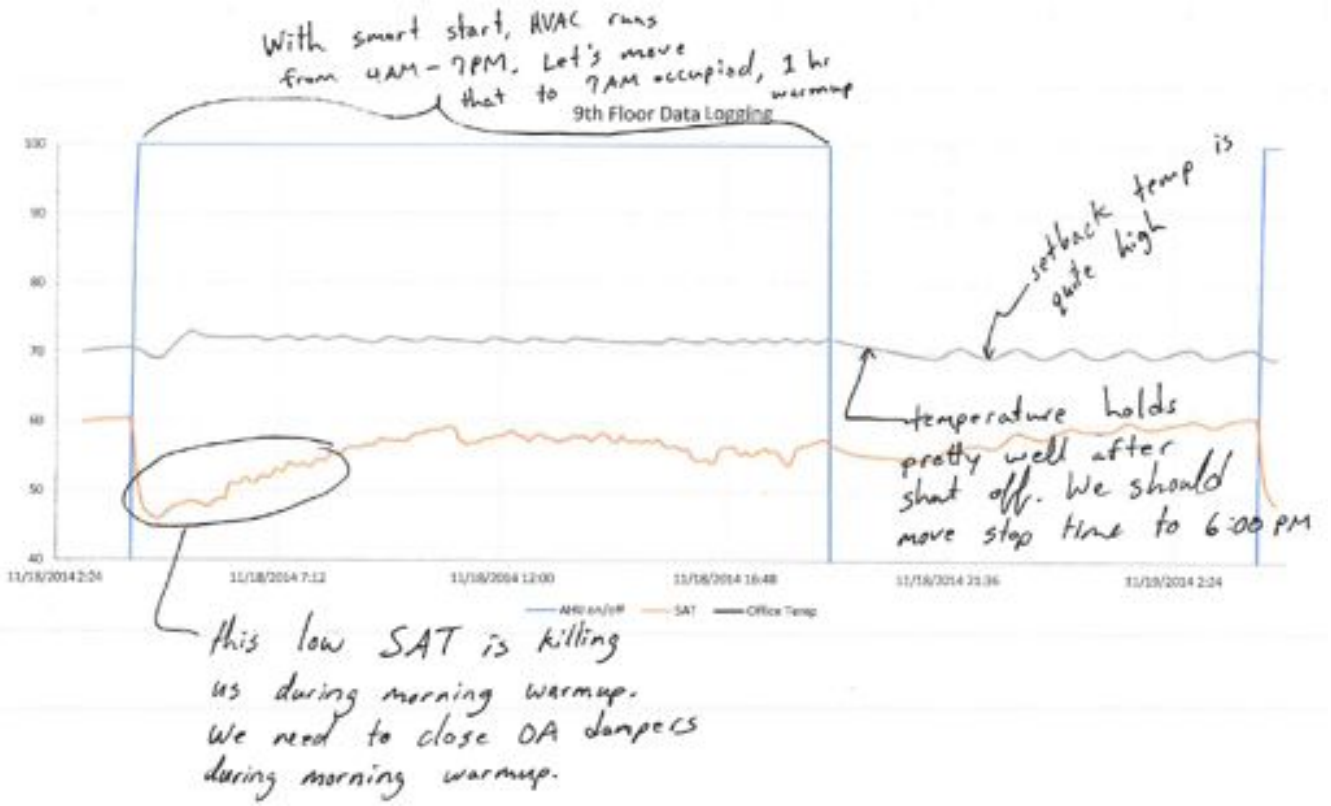
	SP	Actual
AC 11	67	57
AC 13	67	51
AC 14	67	64
AC 15	67	62 → still low
AC 18	67	53 → linkage is disconnected from actuator
AC 20	67	60
AC 21	67	61
AC 22	67	53
AC 23	67	54

AC 22 @ 10%

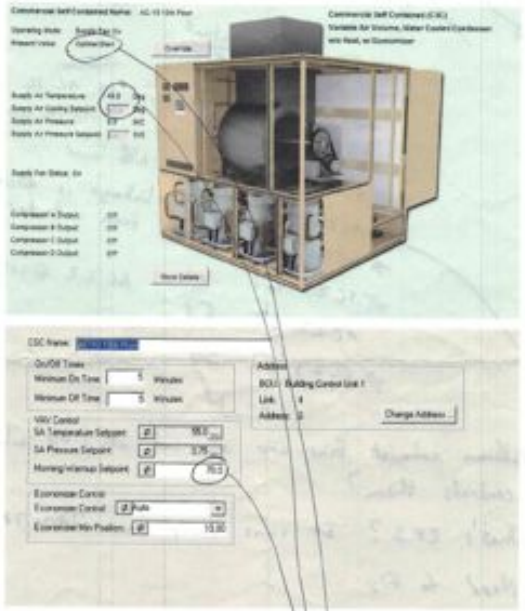
is AC 16 working?
is AC 12 working?

* Bathroom exhaust fans are on sat at 1:00 what controls them?
* What's EF 1? It runs every day 7AM-7PM
* Need to fix

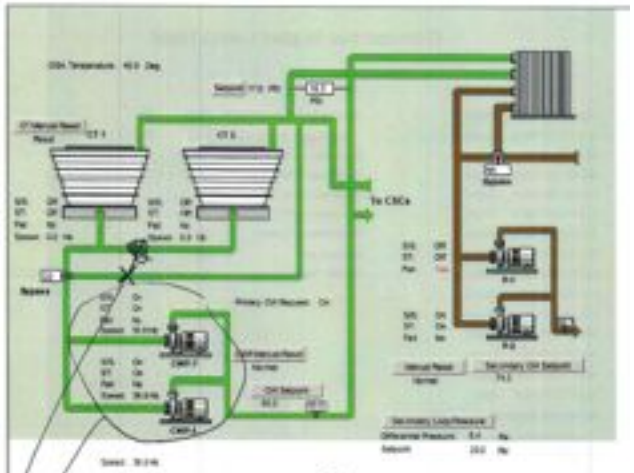
1000 Broadway – Try calculating this at a Measure Level!



1000 Broadway – Try calculating this at a Measure Level!

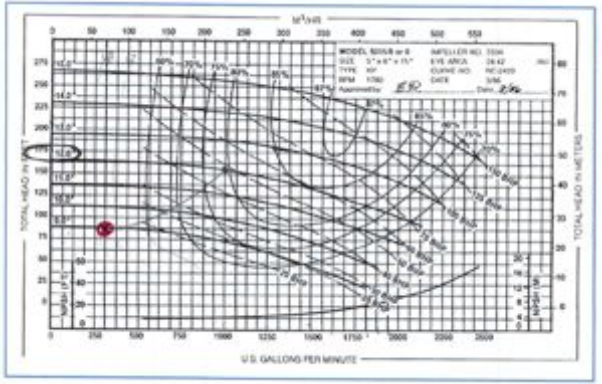


It's in optimal start mode & programmed for a morning warmup temp of 70. Why is the SAT SP 55? This is making it hard to warm up the building.



Can we isolate this?

Need to sequence these. One should suffice most of the time.



Conditions of Service			Motor Data	
Flow:	Temp:	Suct. Press:	HP:	Voltage:
TDH:	S.G.:	Dis. Press:	RPM 1750	Phase:
Fluid:	Visc.:	Diff. Press:	Encl.:	Hz:

GPM	Head	EFF	BHP
375	84'	45%	21.6
500	100'	58%	21.8
750	125'	71%	33.7
1,000	155'	80%	48.1

Summary

- In considering whole building M&V, we should be honest about our current methods
- Measure level analysis:
  - Requires skill not always possessed by those conducting the analysis
  - We consider evaluation results as absolute – they're prone to the same uncertainty as ex-ante
  - Is really tough for RCx measures or "building tuning"
- Whole building analysis:
  - Also contains uncertainty, but it can be better quantified
  - Is more transparent and easily reviewed
  - Is more efficient for RCx measures
  - Supports a more transactive approach to energy efficiency

Thank You

Chris Smith, PE, CEM - Chris@Energy350.com
Kevin Campbell, PE - KCampbell@Energy350.com